on to test his soldered connections (page 62, lines 3-18, Kemp). Mr. Kemp further reported to the fire marshal that he worked in the kitchen Thursday afternoon, starting about 1:00 pm. He indicated that he installed the dishwasher, put a hole in the sink for the instant-hot water connection and drilled a hole in the sink cabinet for the dishwasher line, but did not make the connection to the water supply line. He stated he did have his plumbing torch in the building, but stated no soldering was done on Thursday; "only finish work". (page 61, lines 16-22, page 63 lines 4-24, page 64, lines 1-8, Kemp)

On December 31, 2002, Trooper McGinn conducted a subsequent interview with Mr. Kemp to go over his actions on Thursday in more detail. Regarding a cloth tarp found under the sink by Trooper McGinn, Mr. Kemp stated that Mr. Magnussen had the tarp on the kitchen floor and that he did not use the tarp to protect the area near his soldering. Mr. Kemp further reported to the trooper that he usually uses cardboard or wood to protect nearby surfaces from any dripping solder. Mr. Kemp also stated that Mr. Magnussen folded up the tarp and put it under the sink at the end of the day. There was solder on the tarp, even though Mr. Kemp stated he did not use it for protection under the sink. Regarding what were observed as burn marks within the wood cabinet at locations consistent with soldered joints, Mr. Kemp indicated that he did not make those marks during his soldering operation. (page 52, lines 23-24, page 53, lines 1-7, Kemp). When conducting such a soldering operation, good fire protection practices would include working with a "fire shield" and having a fire extinguisher on hand. No fire extinguisher was reported in the kitchen in the afternoon of Thursday and "rags" used by Mr. Kemp are not considered adequate protective heat shields. NFPA 51B *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 1999 edition, a nationally recognized fire prevention standard states that, "If hot work is done near walls, partitions, ceilings, or roofs of combustible construction, fire-retardant shields or guards shall be provided to prevent ignition. In addition it also requires that, "Fully charged and operable

fire extinguishers that are appropriate for the type of possible fire shall be available immediately at the work area."

Mr. Kemp indicated (both in his statement to the trooper and later in his deposition) that he realized late in the day (approximately 3:00 pm) that the garbage disposal would not fit within the space of the sink because the sink pipes were in the way. He stated he would have to move the hot and cold water stops under the sink on Friday. To do this requires the use of the plumber's torch to heat the soldered joints in order to rearrange the pipe configuration. Mr. MacLaughlin indicated to us, upon his examination of the evidence that a number of fittings/pipes, etc, would need to be moved in order to accommodate the garbage disposal and that a turning of one of the valves (as was initially assessed by Mr. Kemp in his reporting to the trooper and later in his deposition {page 75, lines 23-24, page 76, lines 1-9, Kemp}) would not accomplish the task at hand.

As the investigation progressed and as mentioned, T. J. Klem and Associates provided opportunity for notified parties to examine the scene and to jointly collect evidence. Part of the evidence collected included the kitchen sink and cabinet and the wall stud assembly directly behind the sink. The wall stud area contained the electrical conductors and outlet boxes, as well as the plastic PVC drain piping that Mr. Kemp had already installed. The thermal insulation and its remaining plastic vapor barrier were also collected from the stud bays as was the burned remains of the drop cloth. The copper pipes and stops making up the feeds under the sink were cut off from their risers and taken intact with the cabinet. These too were placed into evidence.

Examined in detail by Mr. Lester MacLaughlin, subsequent to our evidence collection efforts, determined that the cold water valve or stop assembly was loose on the cold water riser pipe. In review of our on-site exam procedures and photographs, we determined that during our initial exam on December 23, 2002, the valve was off of the

cold water riser and lying on the bottom of the kitchen base cabinet. In an effort to understand how all the pieces fit together, etc., during our initial on-site efforts, the valve was found at this location and was placed back on the cold water riser in order to secure it. The valve stayed there, loosely fitted, until examined off-site by Mr. MacLaughlin. We did not realize the significance of the position of the valve until later in the investigation. As a result, our initial actions regarding the valve were not communicated to the parties to the investigation. However, a review of Dedham Fire Department photos taken December 20, 2002, by Lt Fontaine after knock down of the fire and during their initial investigation, shows that the cold water shut off valve assembly was indeed not in place. Finally regarding this matter, our initial photos of the kitchen area, on December 23, 2002, taken before any of our investigation of the fire shows the cold water stop not in place. Photos showing that the stop was off originally were made available to all interested parties via the internet prior to the first joint on-site inspection.

Mr. MacLaughlin made additional observations during his exam of the sink and its related piping. There was soot, he noted, inside the cold water valve body and soot on the short copper nipple where the shut off was attached. The fitting to the flexible cold water line was no longer soldered to the cold water supply, and the inside of this fitting is soot stained, as well. To Mr. MacLaughlin, these were additional indicators that the cold water valve was not attached before the fire, further supporting the early photographic documentation of the fire scene. Additionally, this meant that the main water supply valve had to be in the off position. This is the position of the water supply when soldering is to be done. In contrast, during finish work when the integrity of the connections is tested, the water is turned on. During his deposition, Mr. Kemp stated that he shut off the main water on Wednesday to solder in his stops. He turned the water back on around noon on Wednesday to check for leaks and left it on. He claimed that neither he nor any other person had shut off the water prior to the fire. (page 63, lines 3-15, Kemp)

Subsequent interviews of Dedham Fire Department personnel were conducted to determine if the fire department shut off any water service or saw water coming from the kitchen sink pipes during the fire. Statements from Dedham investigator Lt. Fontaine as well as Chief Driscoll, incident commander during the fire, first arriving Deputy Colantuoni, and Deputy Beltis who took over "mop-up operations" at 8:00 A.M. the day of the fire, all indicate that most of the fire fight was from the outside and that nobody shut off the water service. In addition, no one saw water coming from the kitchen sink area, which, if the water was on, would have been flowing from the open cold water pipe under the sink due to the valve or stop not being in place.

During his deposition, Mr. Kemp described what he would have to do to move the valve handles to allow the garbage disposal to fit. His statements and on-site documentation indicates that the pipes were installed toward the back of the cabinet, within two or three inches of the back wall of the cabinet. This is the common method or location of the stops when using a standard, center drain sink. The Marino sink drained from the rear, however, not the center, and Mr. Kemp admitted that he did not check beforehand the sink drain location. He indicated that he was hoping, at first, to spin the valves ninety degrees to off-set them and hoping that he did not need to move the obstructing pipes. To make any change for the disposal, he stated the joints at the valves would have to be heated with a torch, taken apart, and reconfigured. To do this he indicated, the water would have to be shut off at the main, and the system drained, so pipe connections could be heated and taken apart. Further during his examination, Mr. MacLaughlin held the sink in place over the existing piping and indicated that the pipes too would be in the way of the garbage disposal. Mr. MacLaughlin photographed their relationship to the drain hole in the sink as part of his documentation. The pipes, he indicated, are clearly in the way and would have to be moved, (also see Mr. MacLaughlin's report of this incident).

As part of the on-site investigation, an ease of ignition demonstration was conducted to an interior wall assembly (void of its gypsum finish). An exemplar of polyethylene plastic vapor barrier used to cover the insulation in the carriage house was briefly exposed to an open flame and found to ignite easily (the ignition temperature of polyethylene is between 599-626ºF as stated in the Ignition Handbook) and continue to burn when the flame was removed. During combustion, this combustible plastic vapor barrier will burn in two distinct ways. It will move upward as products of combustion move to preheat the material above it, enhancing vertical fire spread, and next, as more and more of the product burns, it will begin to drip and continue to burn until this portion of the material is consumed. In the mean time however, this dripping, burning material is capable of igniting other materials in a combustible wall assembly that then too become ignited and spread to even more combustibles. (Of additional note is not only the combustibility of the cotton drop cloth but also the well known attribute of cotton to smolder for long periods of time as stated on page 287 of An Introduction to Fire Dynamics. Since the drop cloth was reportedly last placed in the sink cabinet after any soldering, it does not seem plausible that it was the first material ignited. However, the drop cloth was practically consumed and may have affected the growth and spread mechanism through its cited physical properties).

An initial fire development of this nature could be expected to lead to slow growth of the fire until sufficient intensity of the fire is reached and more dramatic fire spread occurs. Eventually these fire growth dynamics resulted in the fire spreading out of the concealed space to adjacent combustibles in the kitchen and then spreading vertically to the second floor (also see later discussion)

The avenues of vertical fire travel can be demonstrated with an understanding of the construction assembly method of the front kitchen wall (a combustible concealed space leading to the second floor). During renovation, the old wall studs in the kitchen

were removed and new framing applied against the bare brick façade. Because of variations in size from brick to brick and inconsistencies of stacking from layer to layer, the vertical plane of the brick façade is not completely smooth, thus the new wall studs and top plate are not in contact with the bricks at every point. This creates gaps between the wood framing and the bricks that allow heated gases and other products of combustion to move both horizontally and vertically. These gaps along the top of the kitchen wall framing allow fire spread into the kitchen ceiling joist bays and further into the combustible concealed space of the second floor. Once burning here, fire and products of combustion can travel vertically again into the roof rafter framing around the second floor dormers, as we see in the Marino photos. (The effect of this wall construction is analogous to fire spread with "balloon-type" wood -frame construction that enables dramatic fire spread to upper floors of buildings. Such construction does not contain fire stops to prevent vertical fire spread.)

Prolonged burning/smoldering, etc. within the large wall assembly (calculated to be 121 sq. ft.), led not only to a fire spread mechanism to the second floor but when the fire penetrated the wall's plywood face, fire spread to the interior of the kitchen (also see later discussion). Buildup of the fire within the kitchen would be a function of the number and location of kitchen cabinets involved at this point. Tests have been conducted on wooden wardrobes (similar to a large kitchen cabinet) and the peak heat release rate in the study was found to be approximately 6400 kW (this value varied depending on the thickness of the wood and the size of the cabinet) (page 3-33 <u>The SFPE Handbook of Fire Protection Engineering</u>). The resulting heat release rate of the burning cabinets may be sufficient to drive the kitchen to flashover or within time the fire would need to spread to other cabinets before the heat release rate of burning items in the kitchen was sufficient to cause flashover. Once flashover of the kitchen occurred the fire protection literature regarding room burning characteristics indicates that burning intensity is

sustained until more and more of the fuels are consumed. As the consumption of the fuels continues the active burning phase (and thus intensity) begins to decline into the "decay phase" of burning for a period of time. This discussion is relevant because the fire was discovered within the kitchen to be well into the decay phase of burning, as noted in the Marino photos. Finally, once flashover occurred the fire would spread to other portions of the carriage house, to this point not involved. Again, dramatic proof of this phenomenon can be seen in the Marino photos, where both horizontal and vertical spread within the building is depicted.

Discussion/Conclusions

We have determined that the fire growth, development and spread patterns of this fire are consistent with an ignition under the sink in the kitchen of the carriage house. Regarding the physical evidence of the fire spread phenomenon, fire patterns were found to uniquely stem from the area under the kitchen sink. As part of the unique ignition and spread pattern from the opening in the wall assembly in this area, we were unable to establish another scientifically based method of fire ignition and spread that could account for the physical evidence, damage and the documented evidence in this area. (Such challenges to investigative determinations are recommended by NFPA 921). Once ignition occurred to the combustible polyethylene within the combustible wall space of the south wall of the carriage house, combustion was continuous until discovered by Mr. Marino. There was an abundant amount of combustible materials within this wall space for continuous propagation and further spread. Development of the fire in this area, and its subsequent spread throughout the kitchen and adjacent areas is consistent with the discovery of the fire at approximately 2:00 am.

Further, based on the physical evidence that we examined, we determined that there was a unique and initial directional fire spread upward to the wooden window sill

and then outward toward other combustible cabinets and like combustible materials within the kitchen. At some point in this open burning phase of the fire, the energy release rate provided by wall materials and cabinets resulted in flashover of the kitchen. During this time and because of the building construction of this south wall, the fire was also able to spread, to the second floor of the building, as observed upon discovery by the Marino photos. The near complete consumption of all combustibles within the kitchen at the time of discovery and the extension of the fire to the second floor dormer area (as seen in the Marino photos) further and uniquely supports the kitchen of the carriage house as the area of fire origin and the advanced state of the fire at the time of discovery.

Regarding ignition sources for the origin of this fire: first, we have identified only one competent heat of ignition in the area of fire origin i.e. under the sink. (Other ignition scenarios were considered and each eliminated for lack of supporting evidence.) This ignition source was most likely the plumber's torch. The physical evidence of the ignition and spread of the fire and the physical condition of the water pipes under the sink support/strongly suggest that Mr. Kemp was soldering pipes, late in the day; the day before the fire, upon discovering that he had to move various pipes to accommodate the garbage disposal. The combination of openings in the rear of the sink cabinet, readily available, easily ignitable materials at these openings, a competent ignition source and the awkward access that a plumber would have to unsoldering the water pipes (see discussion below) were components of the ignition scenario. Further supporting this determination, we concluded that the water was off at the time of the fire; a physical condition necessary for soldering. In addition, the physical evidence indicates that the cold water valve was not in place at the time of the fire. Finally, there is no scientific basis/phenomenon, etc. for the unsoldering of the valve by the fire. Evidence indicates

that temperatures in the area were not sufficient to melt the solder and no other soldered joints (even at the same horizontal plane) were affected.

We have deduced that other factors might have affected the ignition of the combustibles by the torch. Once the sink was in place that day, access to the water pipes for soldering would likely require Mr. Kemp to physically enter the cabinet area or at least the sink would have required alteration of Mr. Kemp's stated working position (i.e. working from his knees, see page 60, line 6 of his deposition) Considering the reported 3" length of the flame of the plumber's torch, the close proximity of the soldered joint in question, the opening in the cabinet where polyethylene and other combustibles were located, and ease of ignition of the polyethylene, ignition within the combustible concealed space can occur.

Physical evidence shows that major re-arrangements of the plumbing under the sink had to occur so that the garbage disposal could be fitted into place. This re-location would require the use of the torch to un-solder the joints, piping, etc. (Mr. Kemp admitted that he did not use what are considered appropriate heat shields during the use of the torch in the building but may have used rags or cellulose materials. Coupled with the cotton drop cloth placed in the sink cabinet, we cannot rule out these materials' involvement in the ignition and fire spread scenario). There were no reports of water running at this area. Mr. Kemp reports that the water was on to the building when he left for the day. Finally, we determined that there was no fire extinguisher present with Mr. Kemp on the day before the fire. Another "violation" of good fire prevention practices during soldering operations.

After ignition, the progression of fire within the combustible void space took place over a period of several hours. The plumber left the premises at around 4:00 PM and the fire was not detected until approximately 2:00 AM the following morning. Within this time frame the fire was slowly developing into the magnitude of open

flaming/free burning phase which was observed by Mr. Marino. Fires typically progress through a variety of stages including: incipient (start of the fire with no active flaming), free burning (flame production period), and smoldering (decreased heat production) (pg. 2-76 of Fire Protection Handbook). The amount of ventilation and the fuel load can affect the fire development between stages. In addition, changes in ventilation may alter the fire progression and cause it to evolve from a smoldering stage to a flaming stage and vice versa.

Because of the lack of natural air supply (or limited supply) within the combustible void space, a fire in this area could be considered ventilation limited and smolder for a substantial period of time before proceeding to flaming combustion. "This transition is not currently predictable; it strongly depends on aeration and flow velocity at the smolder region" (pg. 190 Principles of Fire Behavior). In addition, the front of the entire void space was lined with a polyethylene vapor barrier. This material is readily ignitable and as it burns it also drips hot liquefied-type plastic downwards. This scorching, melted polyethylene is capable of heating up the wood framing members and causing them to smolder and eventually ignite.

The fire ultimately spread out of the void space and into the kitchen area consuming the combustibles within the room. As more and more combustibles became involved, the fire developed and eventually flashed over the room. Once the majority of the combustibles were consumed by the flames, the fire began to decay. This decay state of burning within the kitchen was documented and observed in the photographs taken by Mr. Marino on the morning of the fire. Based on the type of combustibles contained within the room (mostly hardwood cabinets) the kitchen would have taken longer to reach the decay period than that observed with a representative bedroom or living room (rooms containing upholstered furniture, e.g.), as is typically measured in laboratory fire tests. "Heavy, wood-based furniture usually causes slow fire growth but

can burn for a long time" (page 211 of Enclosure Fire Dynamics). A good estimate of time (based on experience and data from the literature) for the kitchen to have been burning prior to Marino photographing the carriage house is at least thirty to fourth-five minutes; perhaps as long as an hour.

During the period of time after the plumber left the house, a slow build-up of the fire occurred within this combustible wall space until the intensity of the fire broke into the kitchen and began to consume all combustibles there. During this intense burning phase of the fire, the fire spread both externally and internally (through voids in the wall cavity) to the second floor. It was at this phase (i.e. kitchen in decay burning and active burning on the second floor) that the fire was discovered. Physical evidence of the burning dynamics was captured on film by the Marino photos that fully support the fire growth dynamics detailed above.

The analysis and opinions expressed in this report are based on my knowledge of facts and information as of the date of this report. If additional data becomes available, we reserve the right to amend this report.

Thomas J. Klem CFI (IAAI)
Fire Protection Engineer, MScFPE
T. J. Klem & Associates, LLC

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